Aims of the Session

- What is Amplitude
- Factors affecting Amplitudes
- Amplitudes in processing
- Data dependent/independent Scaling

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At the end of this Session, you will be able to:

- Define what amplitude is.
- Define the units of amplitude.
- Describe a wave based on wavelength, period, wavenumber, frequency, amplitude, peak and trough.
- Know typical sampling intervals for Seismic Data.
- Understand how Geophones & Hydrophones work.

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At the end of this Session, you will be able to:

- Describe 4 factors that can cause amplitude losses for seismic data during acquisition.
- Define the term amplitude scaling
- Define the terms data dependant & data independent amplitude scaling.
- Define the term spherical divergence.
- Understand the parameters used to correct for spherical divergence.
- Define the term absorption.
- Describe how applying an exponential gain correction compensates for amplitude losses due to absorption.
- Understand the parameters used for exponential gain control.
- Understand the difference between Time Variant & space Variant scalars.

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At the end of this Session, you will be able to:

- Define Dynamic range
- Understand how decibel values are calculated
- Know the decibel value for common amplitude ratios.
- Understand how applying a gain can affect AVO
- Understand the difference between data dependant & data independent scaling.
- Understand how the different scaling processes are calculated.
- Learn which SFMs apply the scalars discussed in this presentation

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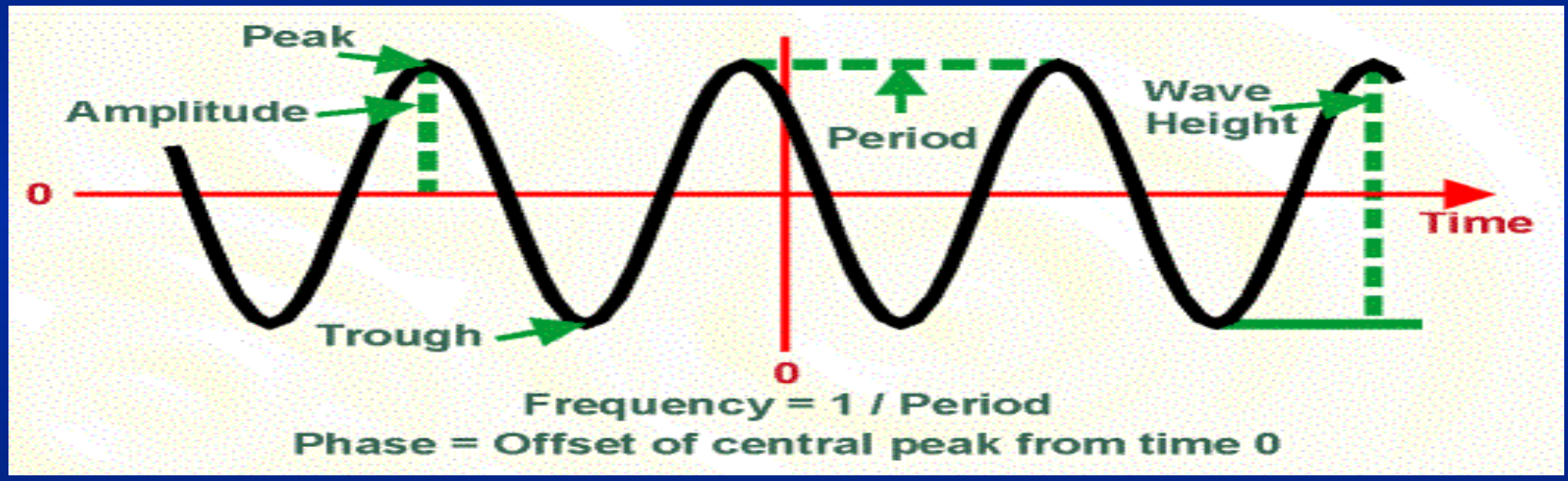
Terminology

The **amplitude** of a wave may be defined as -

‘the maximum departure of the wave from the average value’



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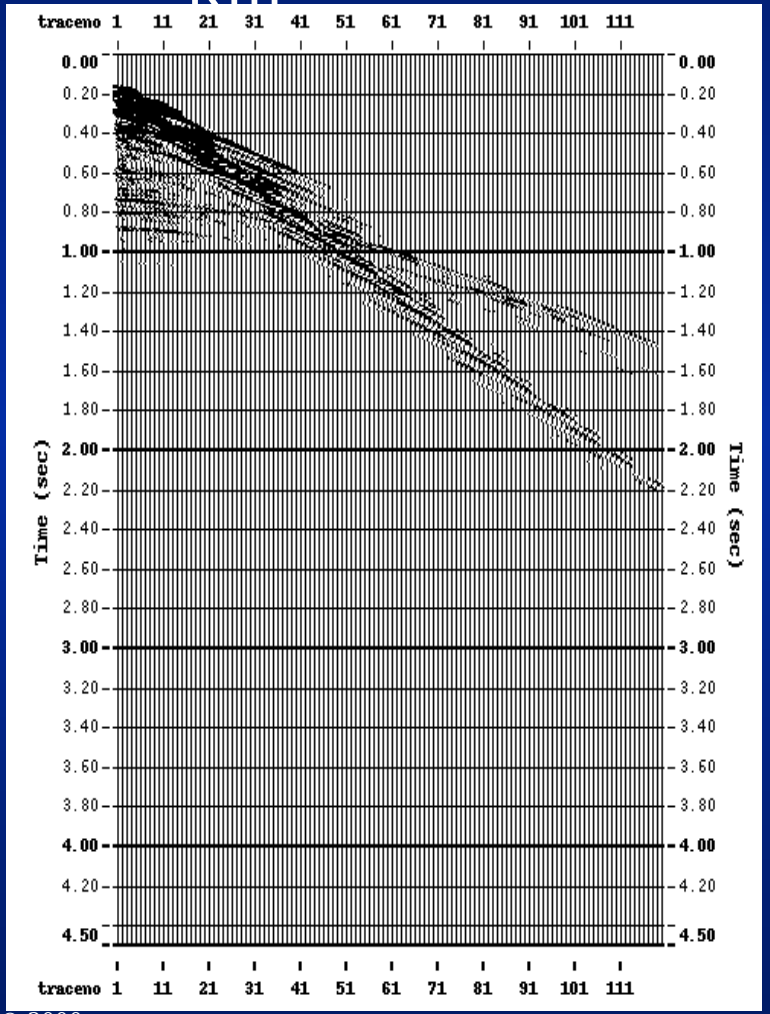
A Shot Record

Distance, Typically 8 km



Listening Time Typically 6 Seconds

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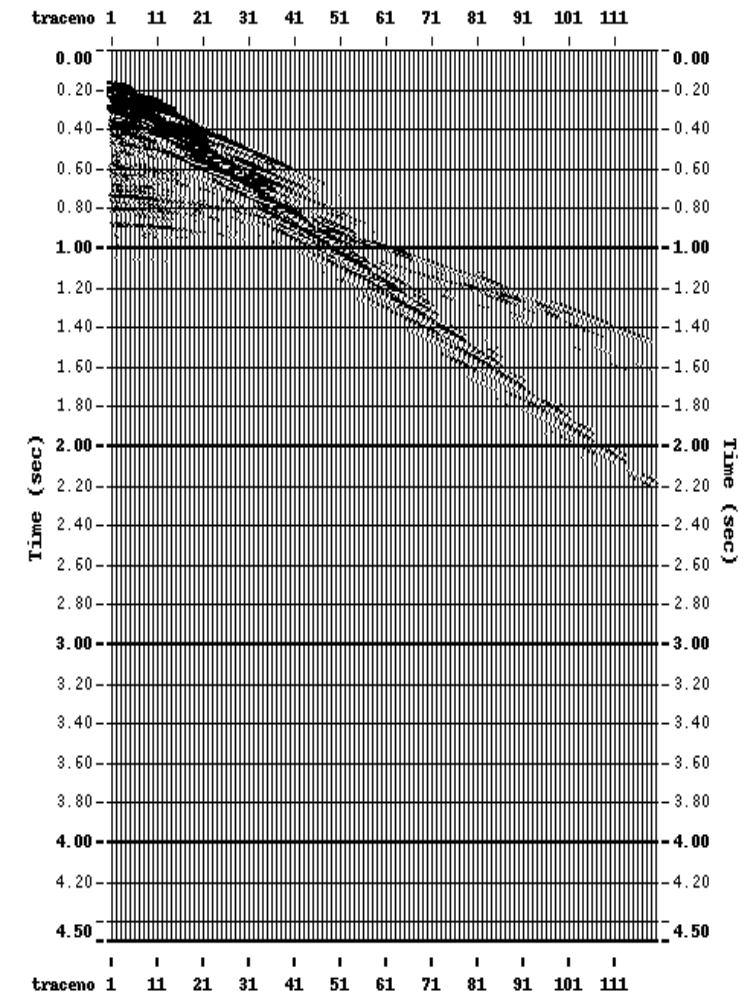
A Shot Record



A shot record is made up of hundred
Of individual traces.

1 trace per receiver location.

If we zoom in on a few traces we can
See their shape.

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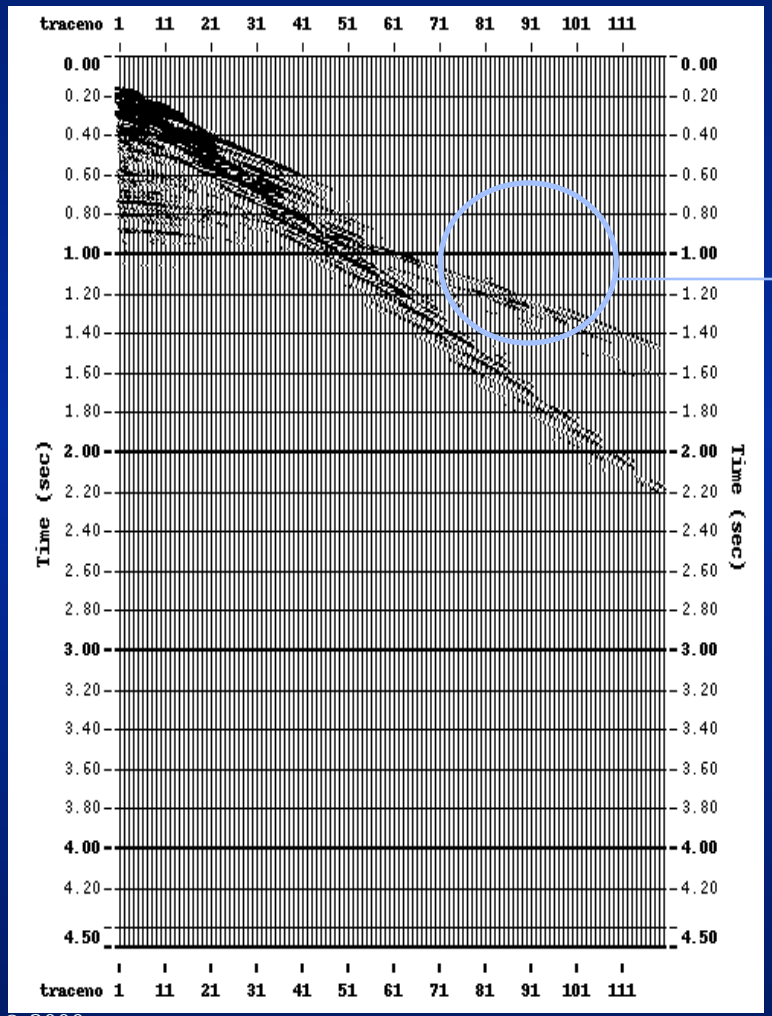
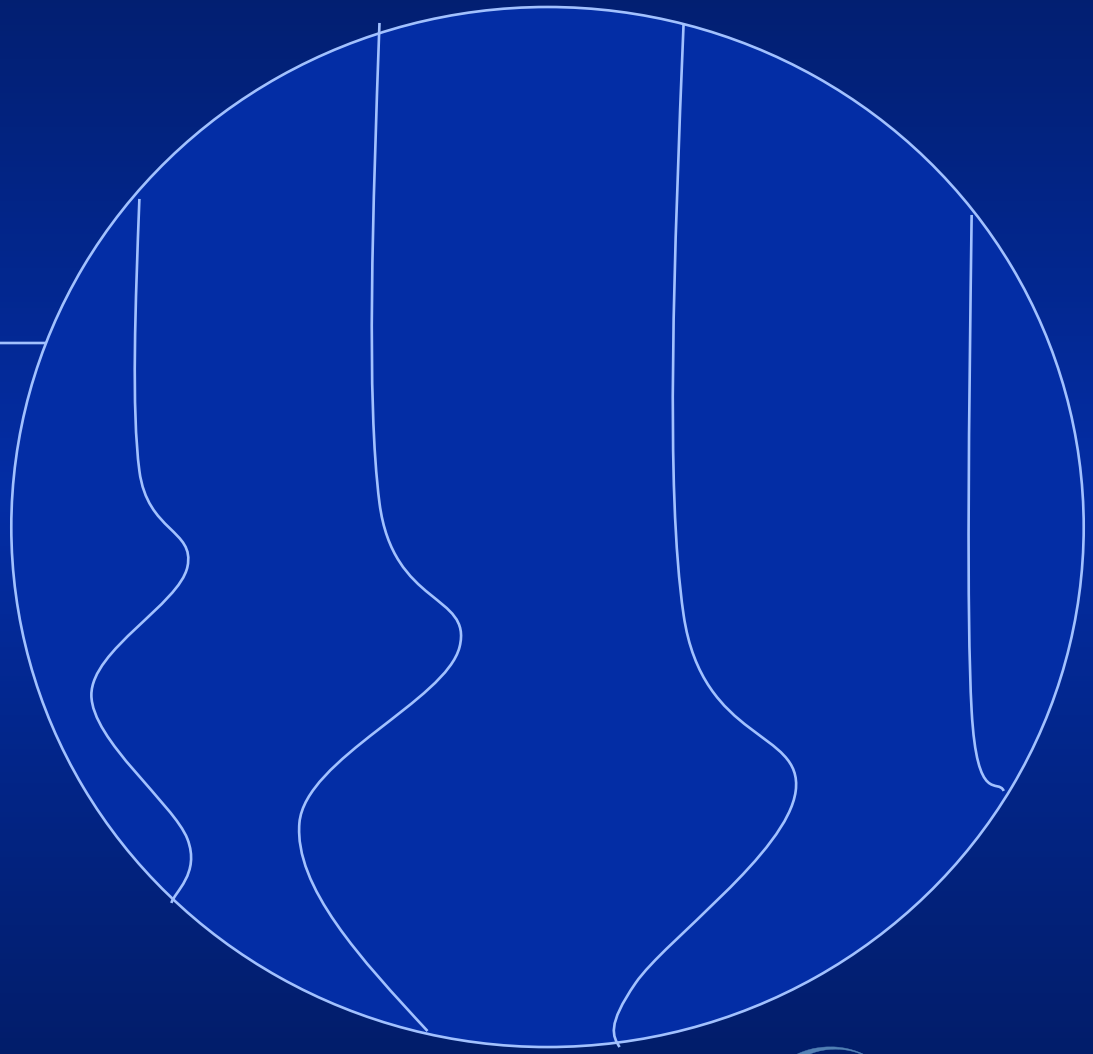
A Shot Record





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A Shot Record

ne traces may look like continuous
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ut this is just the way we like to
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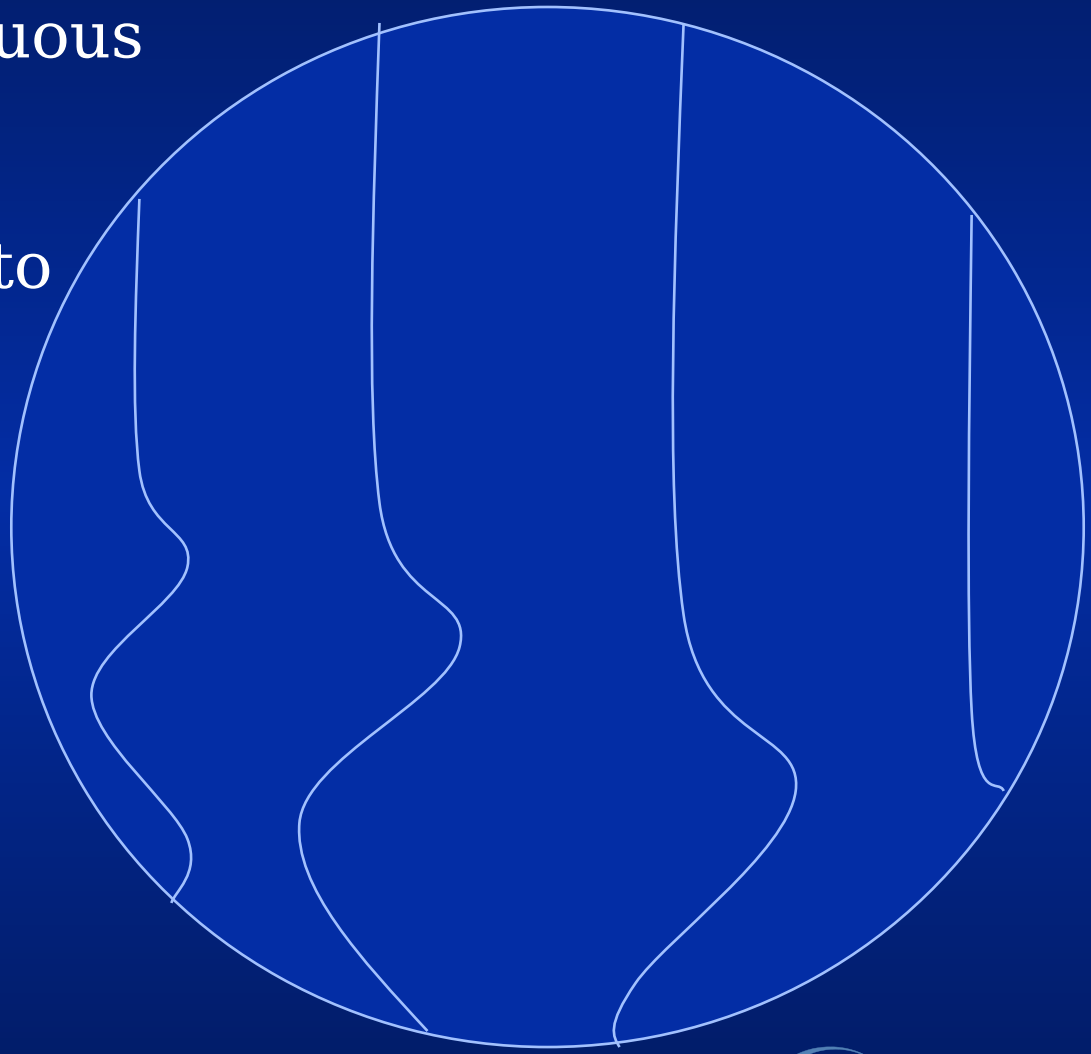

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A Shot Record

ne traces may look like continuous
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ney are infact made up of
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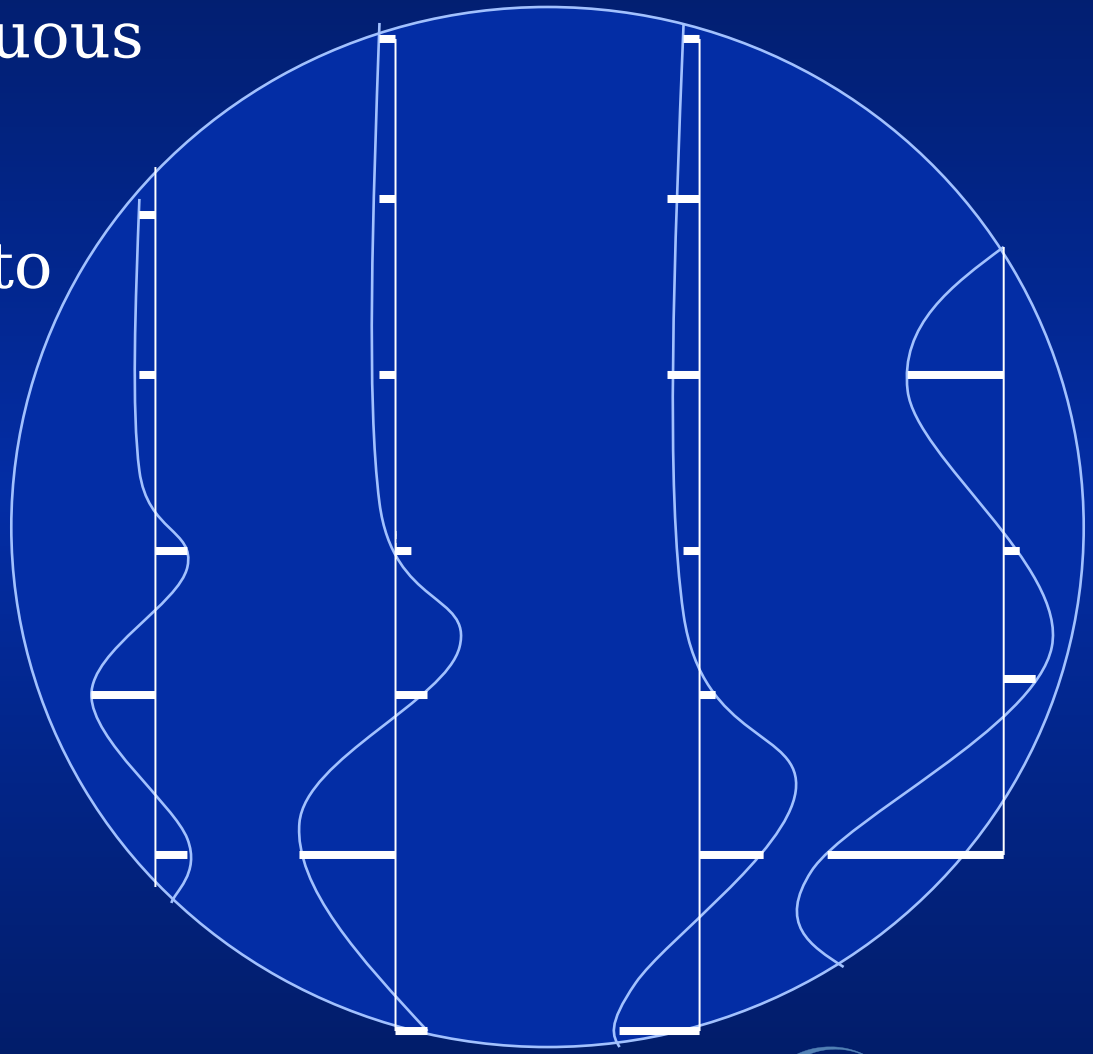

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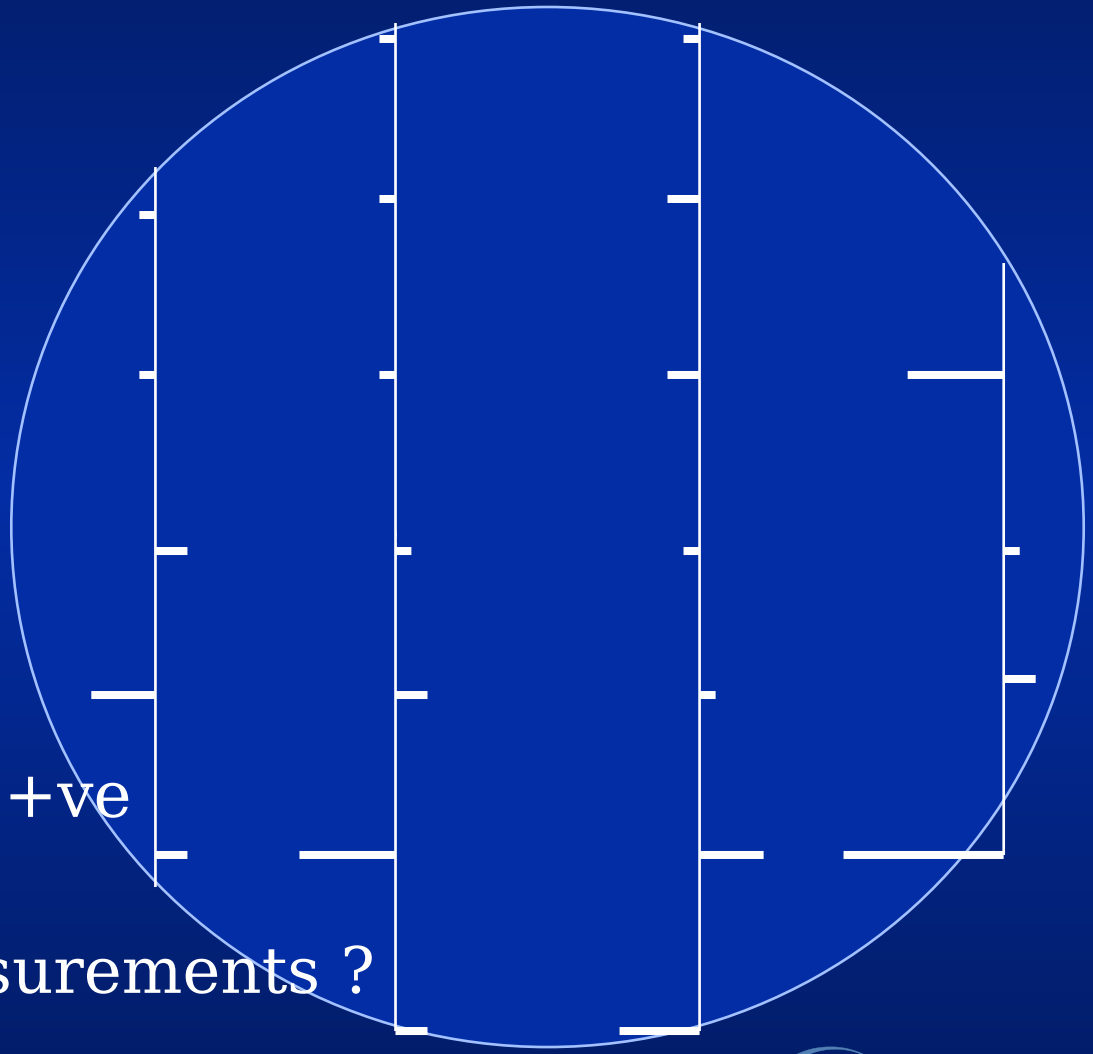
A Shot Record



They are infact made up of Thousands of individual Measurements.

ome of the measurements are +ve
ome -ve

hat are the units of these measurements ?

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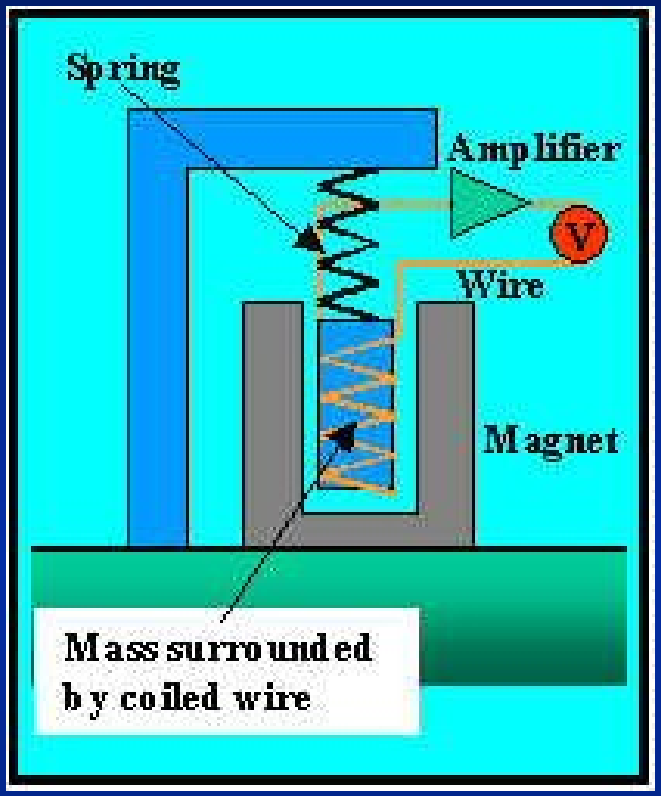
Geophone

- The active element consists of a mass hanging on a spring.
- When the ground moves the mass wants to remain motionless.
- Wrapped around the mass is wire.
- Surrounding the wire-wrapped mass is a magnet attached to the earth.
- As the earth moves, the magnet moves up and down around the mass.
- The magnetic field of the moving magnet produces an electrical voltage in the wire.



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Geophone

- This geophone has it’s side cut off so that you can see the working parts.
- The copper wire wrapped mass can be seen.
- The spring connecting the mass to the case is hidden just above the mass.
- The silver case inside the blue cover is magnetised.
- The black wires coming from the geophone transmit the change of voltage to the recording truck.

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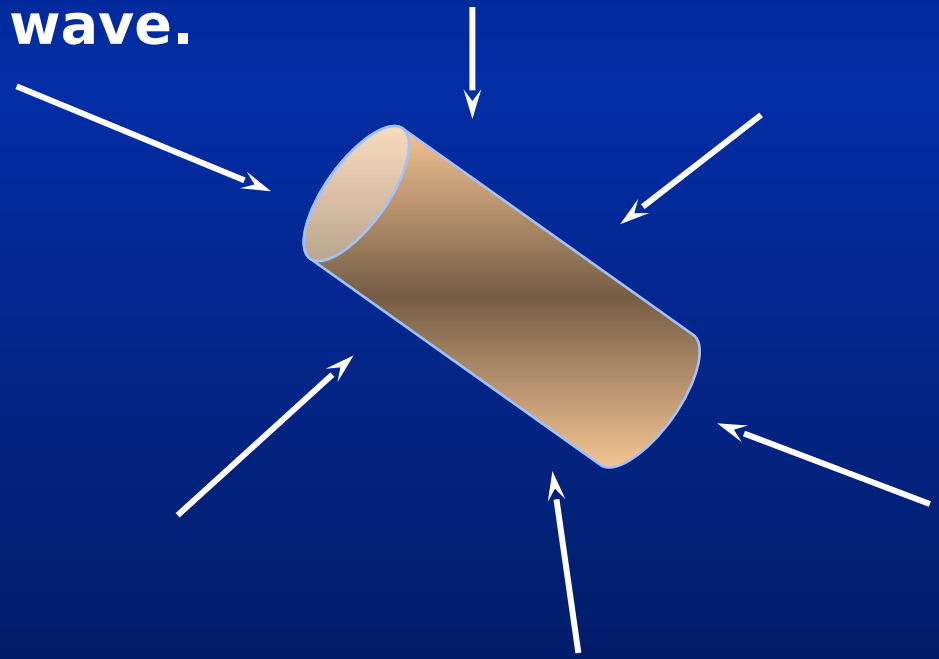
Hydrophone

- A single hydrophone ...
  - a single hydrophone receives a signal equally well from all directions
  - The detectors produce an electrical charge on the opposite faces of the hydrophone when stressed e.g. by a seismic wave.



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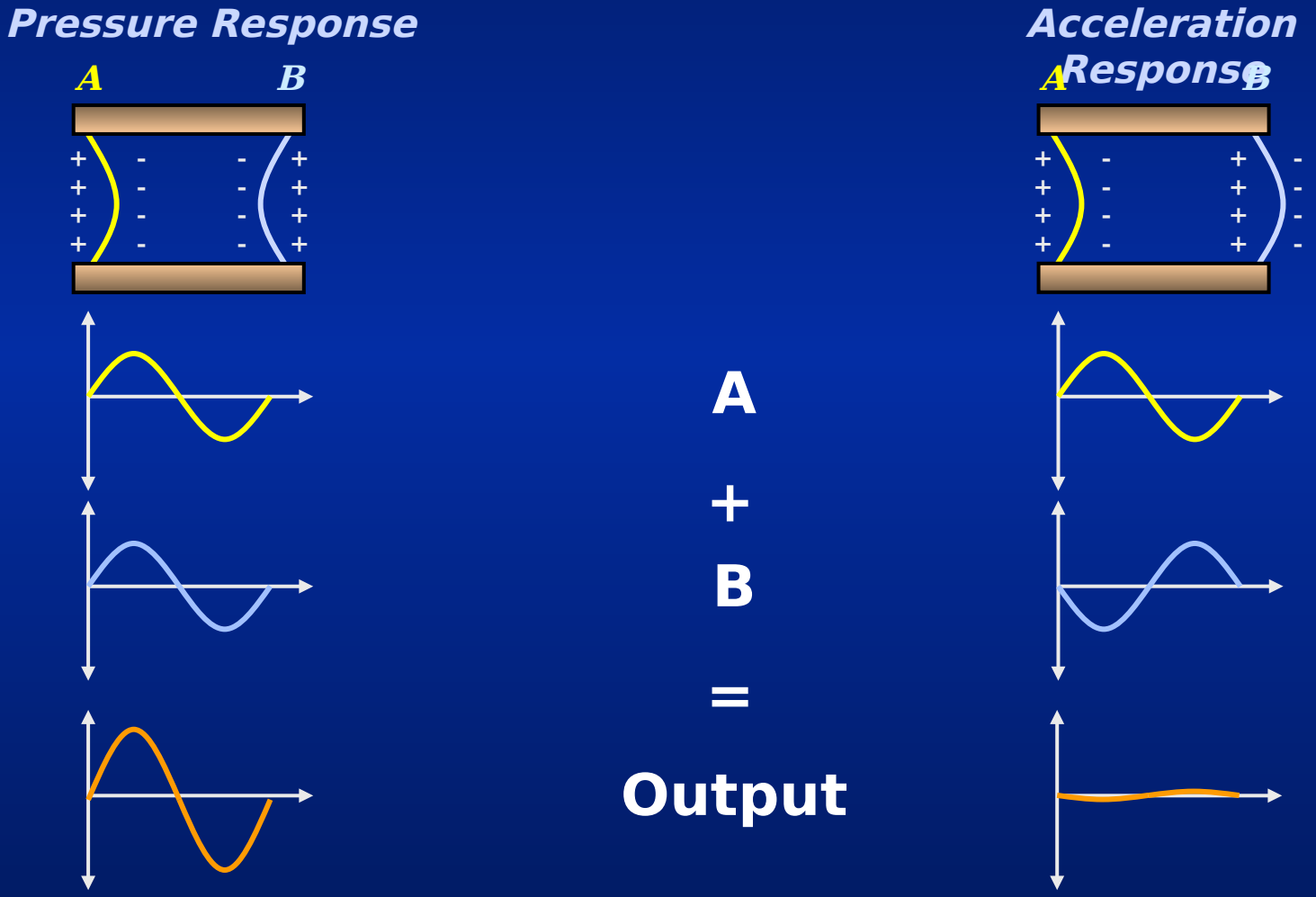
Hydrophone

Acceleration Cancelation



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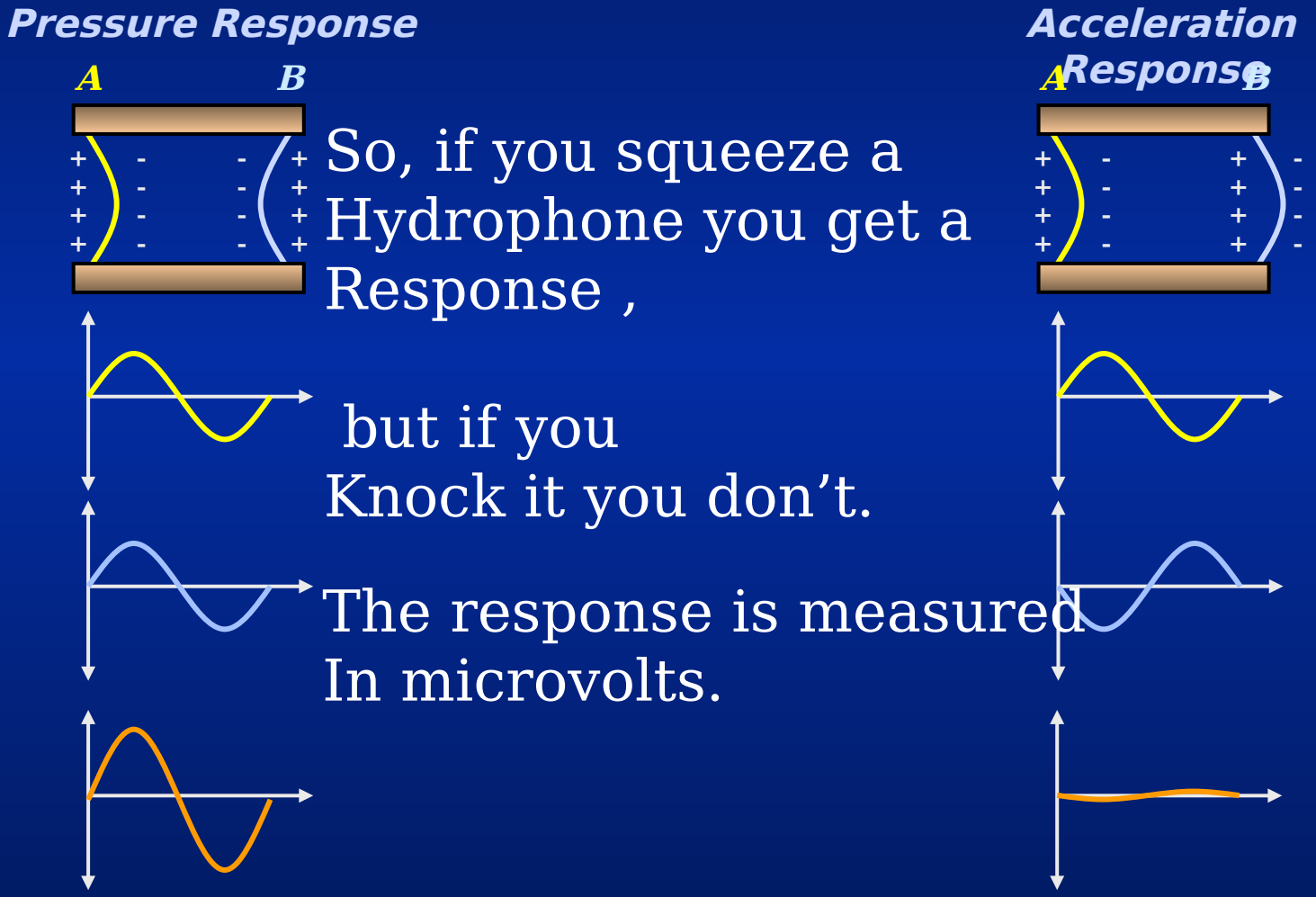
Hydrophone

Acceleration Cancelation



So, if you squeeze a Hydrophone you get a Response ,

but if you Knock it you don't.

The response is measured In microvolts.

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Hydrophones and Geophones

Geophones actually measure velocity Q crew 1 or acceleration Q crew 2. The Voltages produced by the Geophones are proportional to Velocity
Or Acceleration.

Hydrophones actually measure pressure. The Voltages produced By the Hydrophones are proportional to pressure. look at a marine observers log and you may see comments about the degree of noise .. The units the observers use when describing the noise are microbars.. A unit of
Pressure.

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- Describe 4 factors that can cause amplitude losses for seismic data during acquisition.
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The seismic trace

If you were to ask a selection of seismic folk what the units of amplitude
Are, quite a few would have to take an educated guess.

We are more interested in the wave shapes they describe & the size of the
Amplitude relative to other amplitudes.

Seismic recording equipment measures amplitude values every few miliseconds. Commonly every 2ms, but it can be 1ms or even 0.5ms

So a seismic trace would contain general information about the trace, such
As '2ms sample rate' and then the list of amplitude values.

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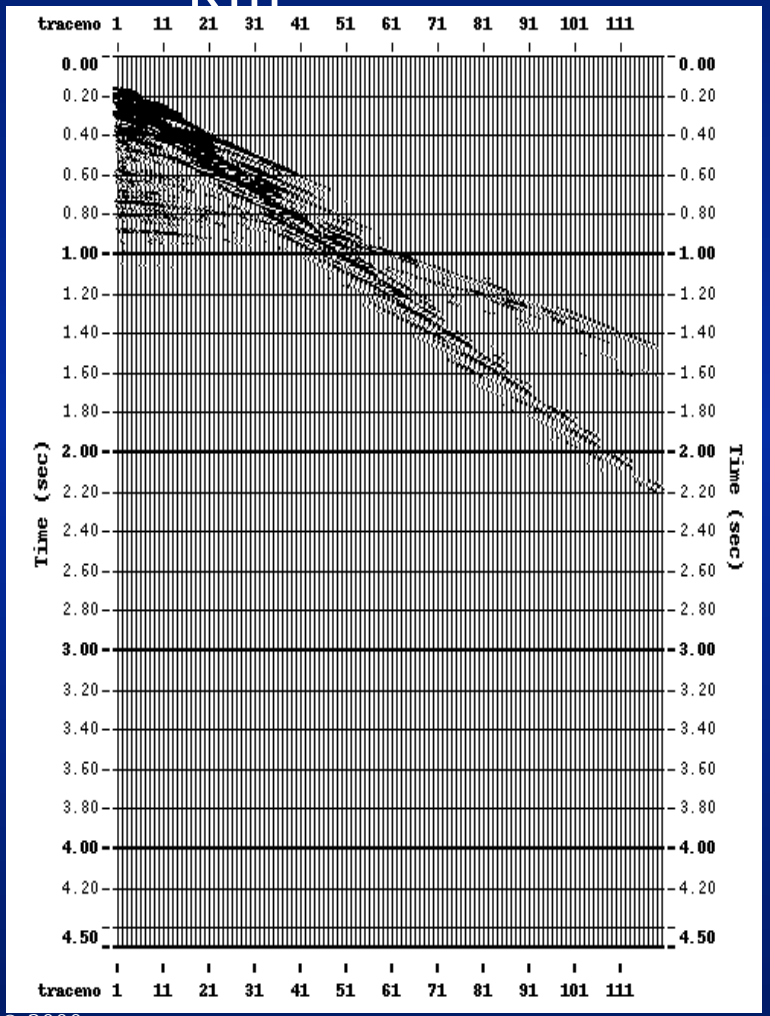
A Shot Record

Distance, Typically 8 km



Listening Time Typically 6 Seconds

Lets look at one shot reco
Again.

Notice how the amplitude
Values get smaller, the
Longer the hydrophones
Listen

After 2.2 seconds the
Amplitudes are so small w
Cant see them.

Why do you think this is?

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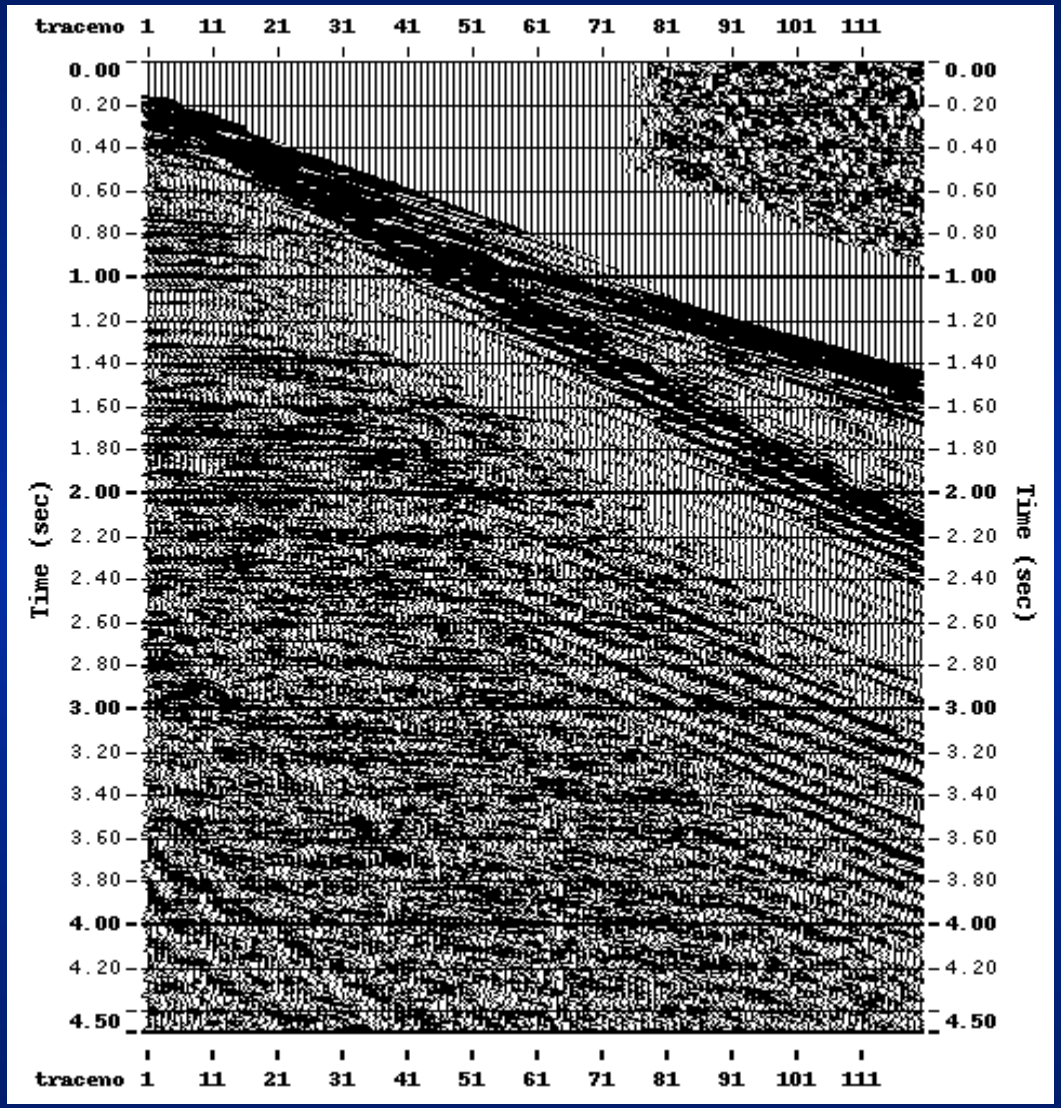
A Shot Record



We were expecting to see something like this, weren't we?

The energy from the air guns spreads out in a sphere.

Just like blowing up a balloon. As the balloon expands the rubber gets thinner. In the same way, as the energy spreads out the amplitudes

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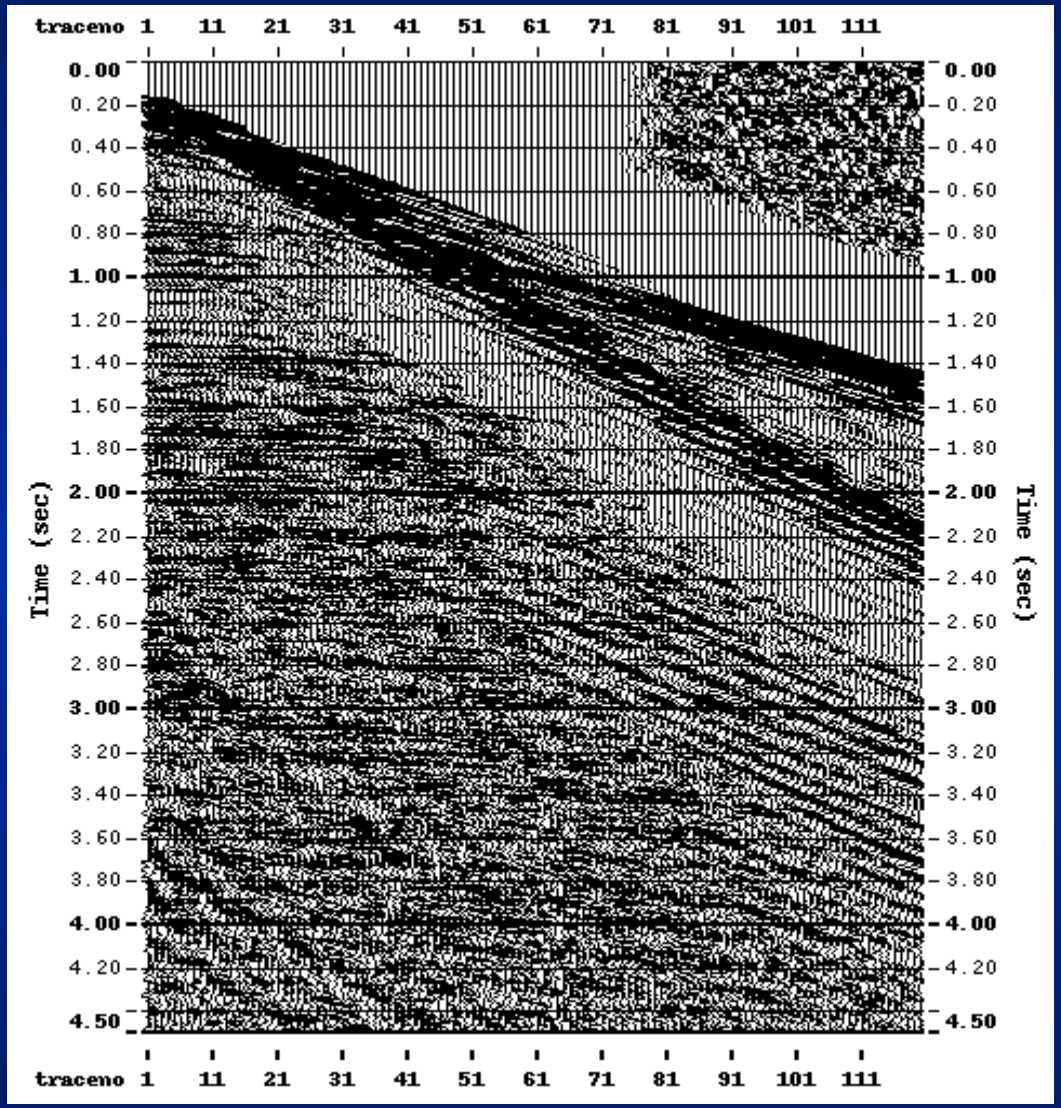
A Shot Record



This Amplitude decay is called Spherical divergence.

In processing we want to correct for this loss of amplitude.

a) So that we can see the data.

b) Some processes such as deconvolution assume the amplitudes don't change with time.

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Spherical Divergence

- The Decrease in wave strength (energy per unit area of wavefront) with distance as a result of geometrical spreading.

- In a homogeneous earth with a constant velocity, the amplitude decay (beside absorption effects) is associated with spherical divergence of the wavefront.

- Because of the increase of velocity with depth further divergence takes place.

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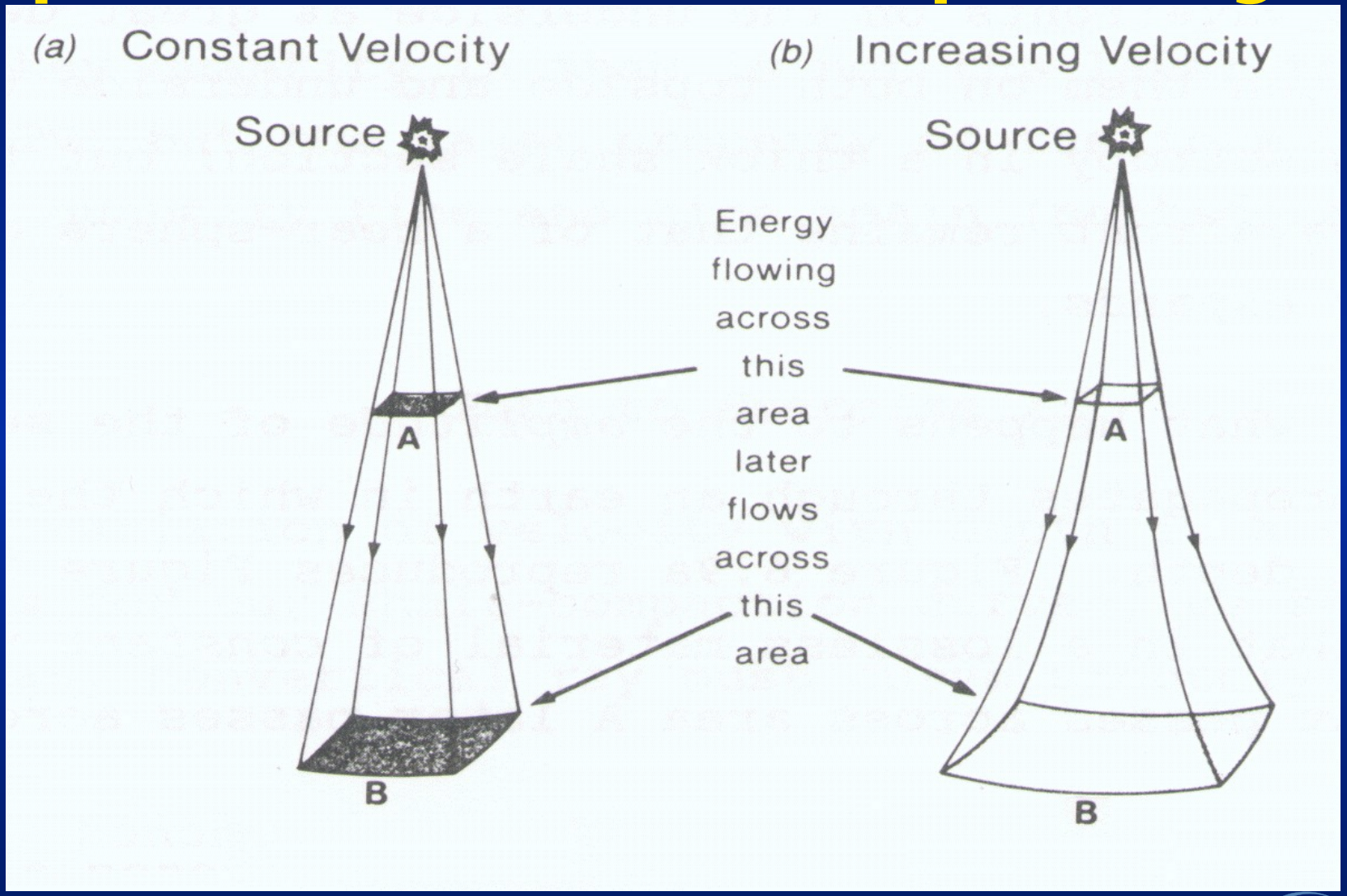
Spherical & Geometric Spreading



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Spherical Divergence

The amplitude decrease is inversely proportional to the distance traveled (**r**, is the radius of spherical wave front)

Amplitude (A) at time **T** $\propto$ **1/r** $\propto$ **1/(V*T),**

For a constant velocity medium, V=const., therefore **A(T)** $\propto$ **1/T**

But in the "layer-cake" model used in CMP stacking, the velocity increases between layers, and in practice it increases with depth within layers, this results in a $\mathbf{TV^2}$ relationship, yielding

(where **V** is RMS velocity of the primary reflections)

A(T) $\propto$ $\mathbf{1/TV^2}$

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For a detailed explanation of $\mathbf{1/TV^2}$ see intouch caseid

Spherical Divergence Compensation

To compensate for the loss due to purely spherical divergence, we can compute a gain "scalar" using:

$$G(T) \propto r \propto VT$$

To compensate for the loss due to geometric spreading with a known velocity field, we can compute the appropriate gain "scalars" using:

$$G(T) = \frac{V^2_{RMS}(T) * T}{V^2_{RMS}(T_0)}$$

Where $V_{RMS}(T)$ is the RMS velocity at time T

When we do not have a velocity field available, we can approximate the TV^2 compensation by using the following relation:

$$G(T) \propto T^2$$

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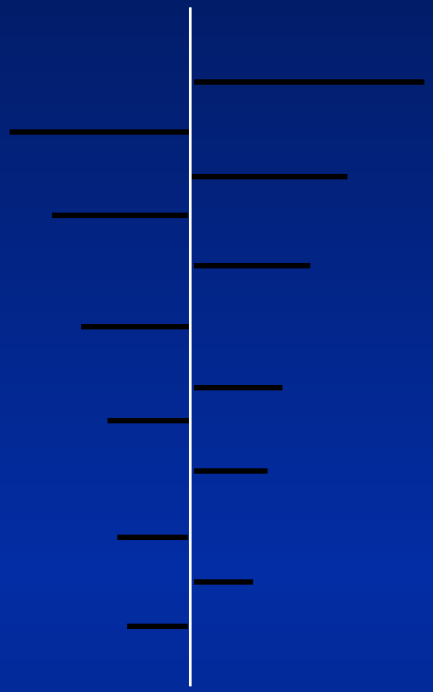
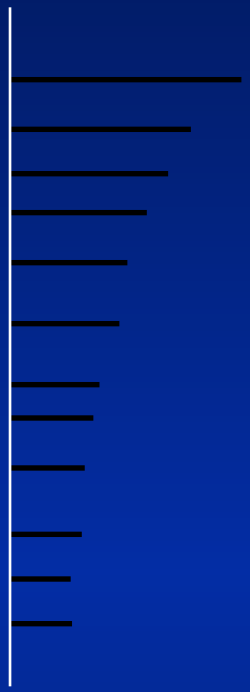
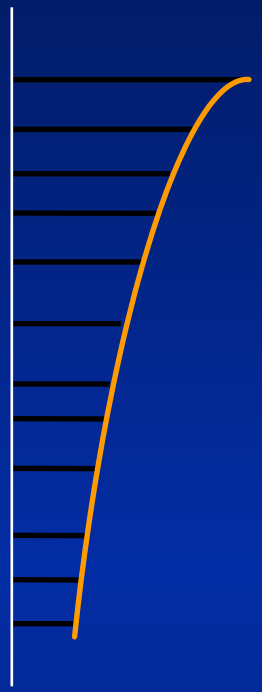
Spherical Divergence Compensation



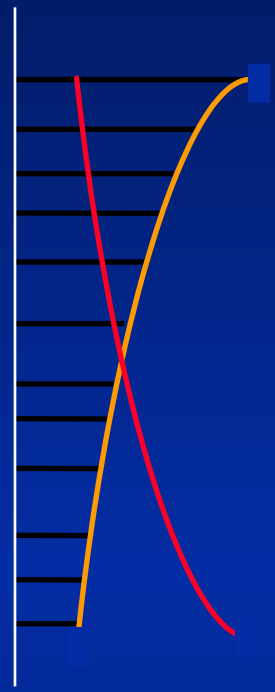
A ‘spike’ representation of a seismic record which has no correction for amplitude decay.



By moving all ‘spikes’ to one side of the axis, a decay function becomes evident.



Draw a curve to fit the amplitude decay.



Apply the **inverse function** to bring all amplitudes to the same order of magnitude.

STOP Time - Compensation is stopped at time value where the stacked signal is expected to fall below the ambient noise level.

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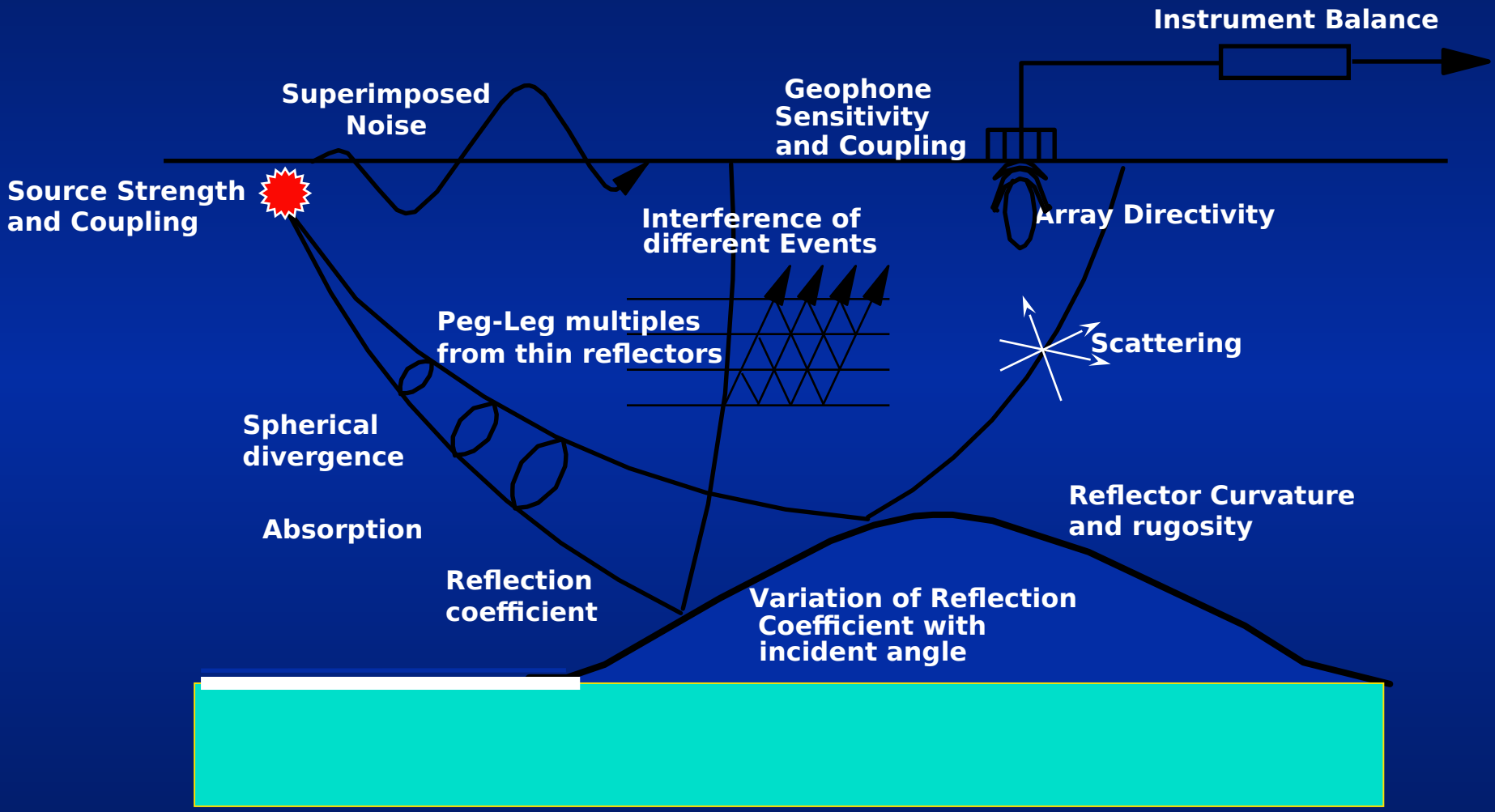
Other Factors which Affect Seismic Amplitudes



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Absorption

- Absorption is a process whereby the energy of a seismic wave is converted to heat while passing through a medium.
- The loss is a result of the elastic movement. Absorption is very much a function of geology.
- Absorption can be expressed as a function of the distance traveled by the seismic wave… implying it is also time variant.

$$A_x = A_0 \; e^{-\alpha x}$$

The key point here is that amplitude decay due to absorption is exponential with distance.

A_x = Amplitude at distance x

A_0 = Amplitude at reference point

α = Attenuation factor (Absorption coefficient)

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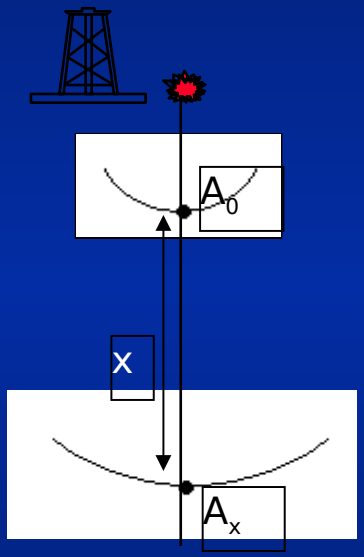
Absorption

$$A_x = A_0 \; e^{-\alpha x}$$



- Absorption is very difficult to explain or model. Core samples lack overburden pressure, while field samples are local and do not represent anisotropy.
- Loss due to absorption seems to be nearly constant per cycle.
- Hence, attenuation is lesser for low frequencies and higher for high frequencies.
- A material for which the absorption is constant per wavelength is also called a ‘constant-Q’ material

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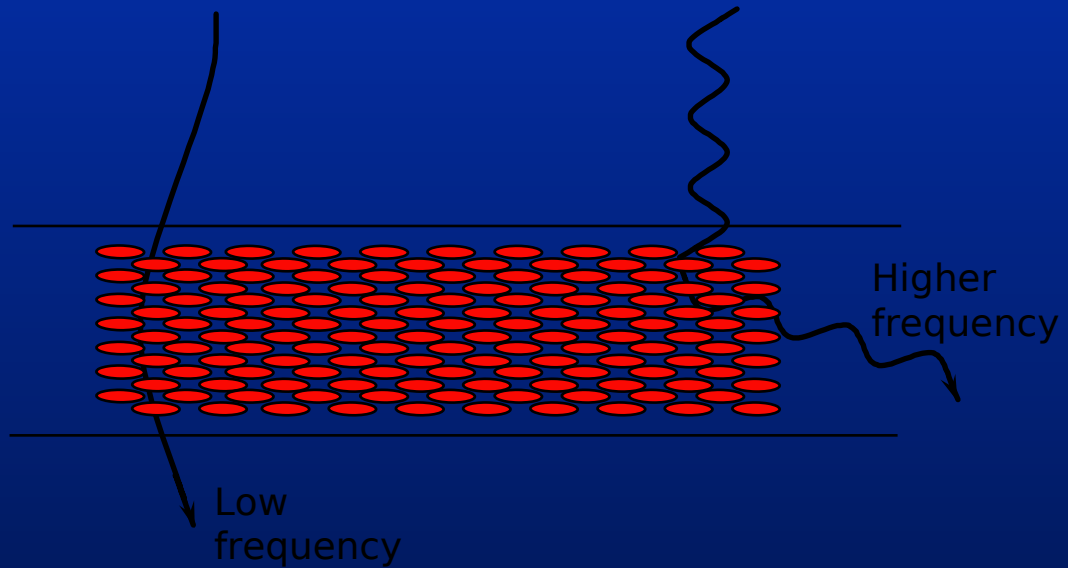
Scattering

- The irregular and diffuse dispersion of energy by inhomogeneities in the medium through which the energy is travelling.

- Scattering is very geology dependent.

- The effect on amplitudes will be dependent on grain size affecting certain frequencies.

- Water content also has an effect.



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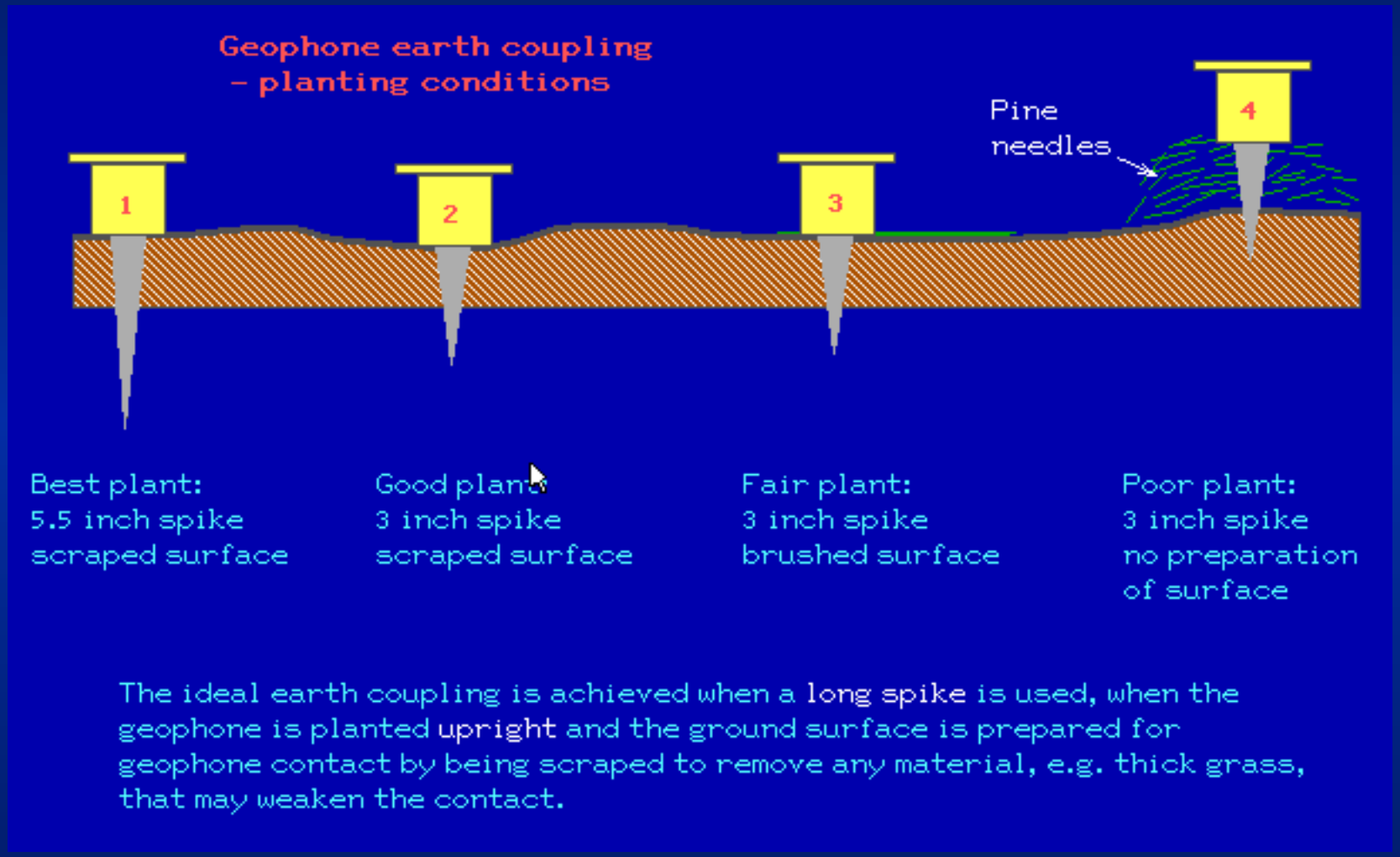
Geophone Planting



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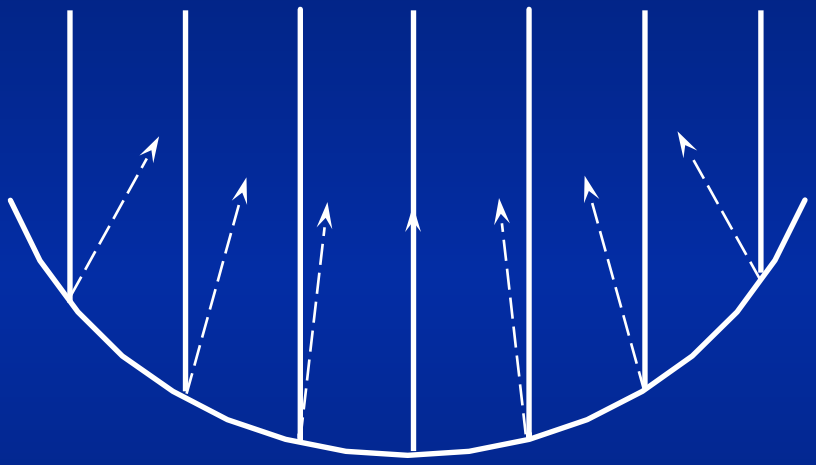
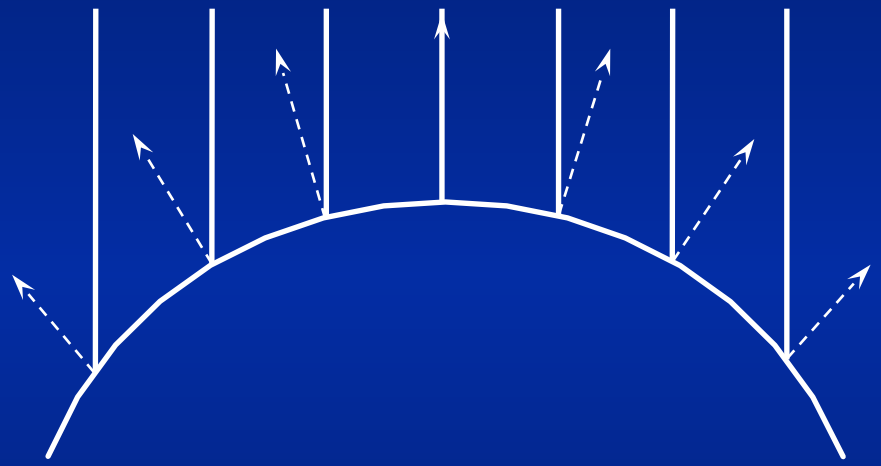
Ray Paths

- **Geometric effects can cause variations in amplitudes as recorded due to a "Lens" effect.**



Energy concentration (amplitude increase)



Energy dispersion (amplitude decrease)

Focusing Effects

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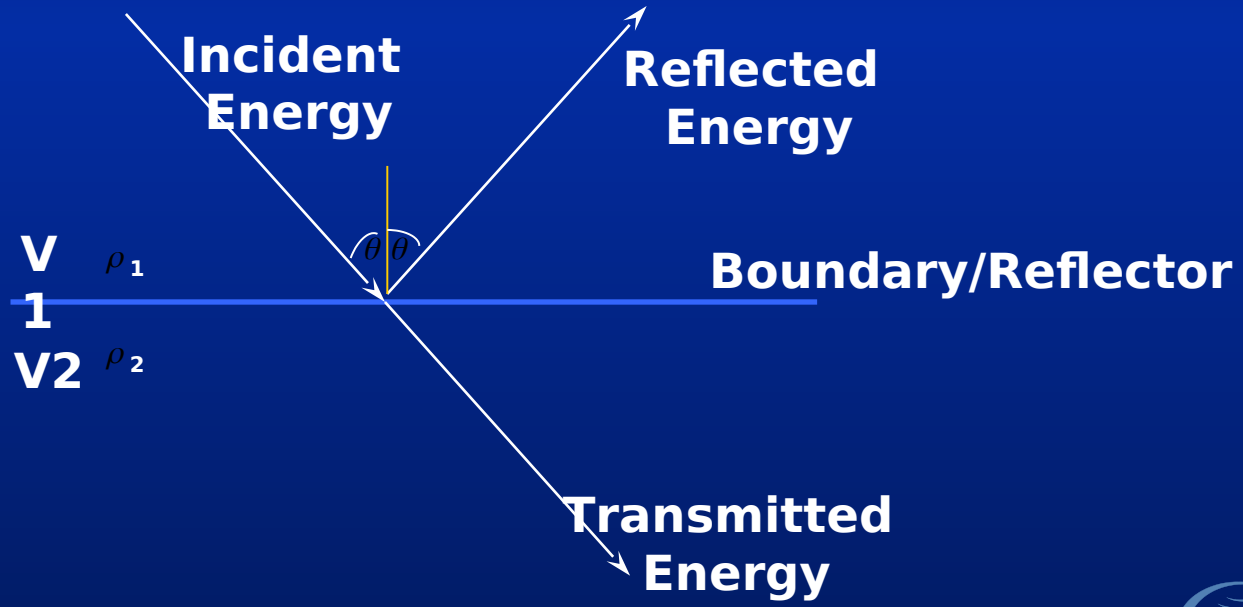
Interfaces

- When acoustic energy impinges on an interface between two layers
- With different elastic properties within the earth two things can happen:
  - Energy is reflected
  - Energy is transmitted
- Ray theory gives the best visual representation



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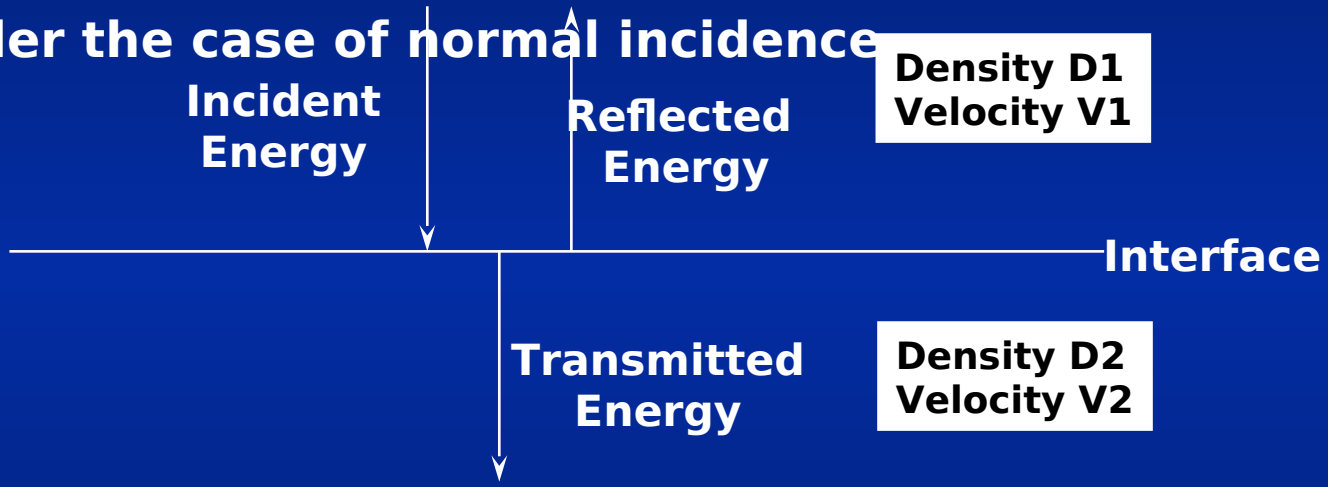
Reflection Coefficient

- **Reflection Coefficient (reflectivity) RC = Amplitude of reflected wave**

  Amplitude of incident wave

- **Consider the case of normal incidence**



At normal incidence: RC = D2V2 - D1.V1

D2.V2 + D1.V1

- **The quantity DV is the ACOUSTIC IMPEDANCE of the material**

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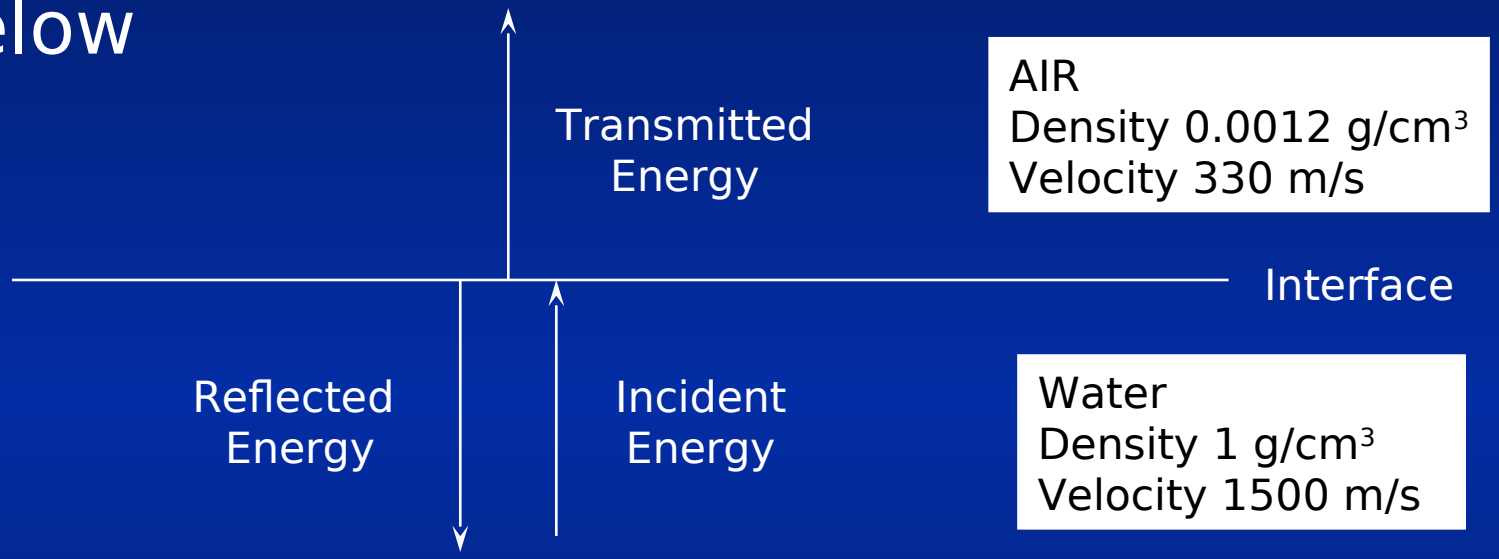
Reflection Coefficient - Example

Wave incident on the water - air interface from below



$RC = (0.4 \cdot 1500) / (0.4 + 1500) \approx 1$

1 implies: all energy is reflected and a phase change occurs (180 deg

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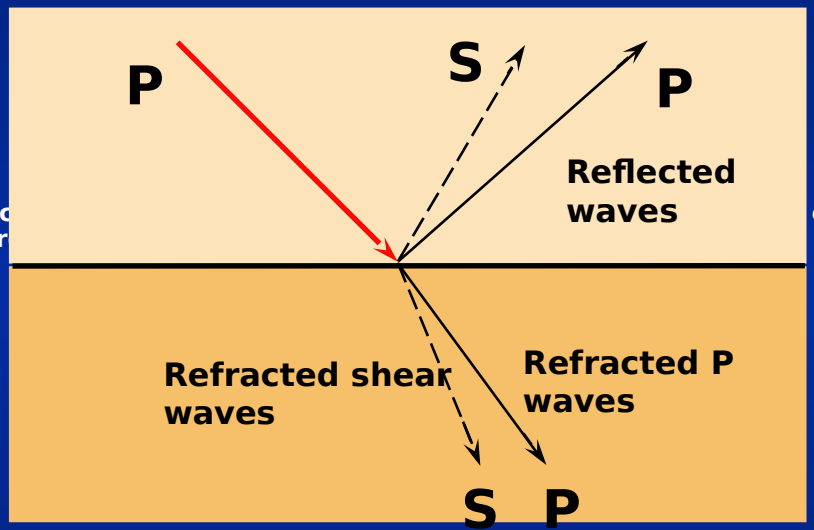
Mode Conversion

(transmission losses)

- Compressional or 'P' wave on incidence at non-normal incidence will suffer mode conversion to shear or 'S' waves.

- The conversion becomes signific of particle movement is available to generate both reflected and r



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- Understand how the different scaling processes are calculated.
- Learn which SFMs apply the scalars discussed in this presentation

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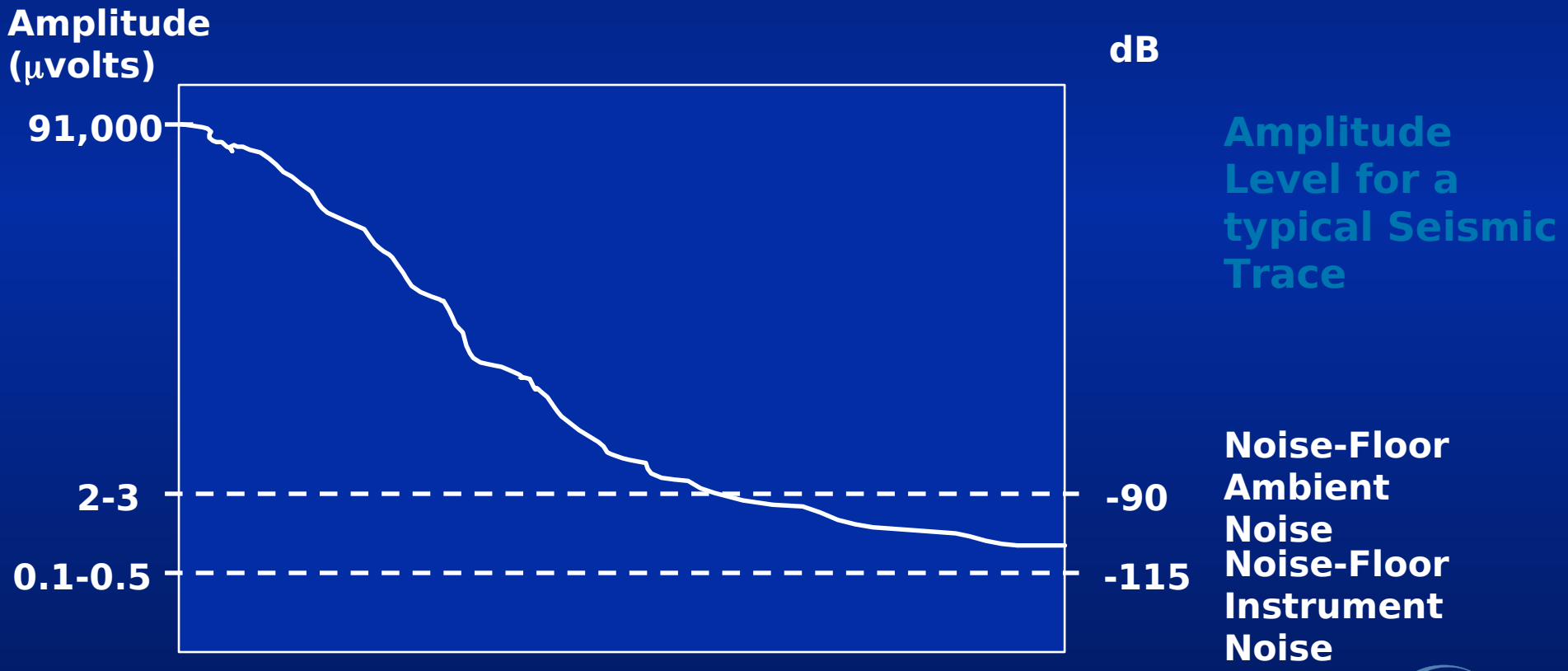
Dynamic Range

The ratio of or difference between the highest and the lowest reading, or strongest and weakest signal, that can be recorded or reproduced by an instrument without change of scale



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Decibel Scale

- **Since the dynamic range is quite large, from 91,000 μbars - 2 μbars, we need a more convenient way of representing the data.**

- **We use a unit of measurement that compares the relative intensity of the signal. It is known as the decibel scale after Alexander Graham Bell, the American inventor.**

- **The relationship between two amplitudes A_1 and A_2 is expressed as N decibels where**

$$N = 20 \log_{10} \frac{A_1}{A_2}$$

For our “typical” seismic trace, the ambient noise floor is,

= 20 * log (2/91,000) = 20 * (-4.6580)

= -93.16 dB from the highest sample

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Some Common dB values

dB		Ratio
3dB	⇒	1.4 : 1
6dB	⇒	2 : 1
10dB	⇒	3 : 1
12dB	⇒	4 : 1
20dB	⇒	10 : 1
40dB	⇒	100:1
60dB	⇒	1000:1

Also note

1d ≈ 10%

+1d ⇒ 10% + 1% = 11%

1db ⇒ 1%

1db ≈ 1%

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Decibel Scale

Common ratios that are often used (some approximate) are :

RATIO	+/-dB	RATIO
1	0	1
0.9	1	1.1
1/√2	3	√2
0.5	6	2
0.3	10	3
0.1	20	10
0.01	40	100
0.001	60	1000
0.0001	80	10000
1	0	1

If the ratio is greater than 1 the decibel value is positive; if the ratio is less than 1 it is negative.

Power varies as the square of amplitude, therefore the dB computation for a power ratio is : $\frac{E_2}{E_1} = 10 \log \frac{A_2^2}{A_1^2}$

Ratio in dB = 10 log

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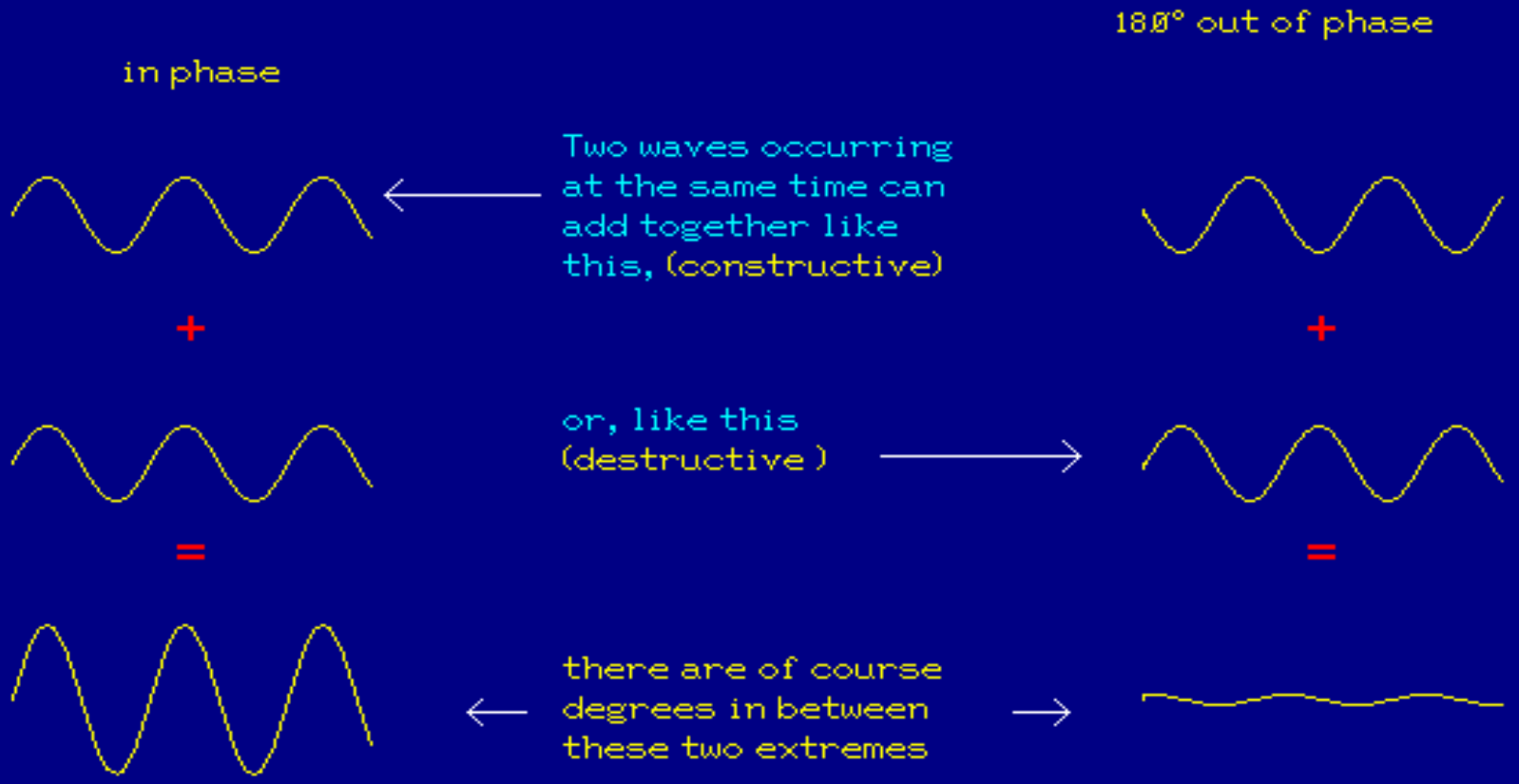
Constructive/Destructive Interference

If more than one signal is received at a time it is recorded as one.
Simultaneous signals can then interfere with each other.

Interference can be constructive or destructive.



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Superimposed Noise

In both marine and land, there are many sources of superimposed noise.

Marine

- **Rough sea, swell**
- **Wind**
- **Other vessels**
- **Trawling nets**
- **Seismic interference**
- **Rigs**
- **Cable jerk**
- **Feathering**
- **Fish / Sharks!**
- **etc...**

Land

- **Bad weather**
- **Traffic**
- **Pedestrians**
- **Bad geophone planting**
- **Wildlife / Camels!**
- **etc...**

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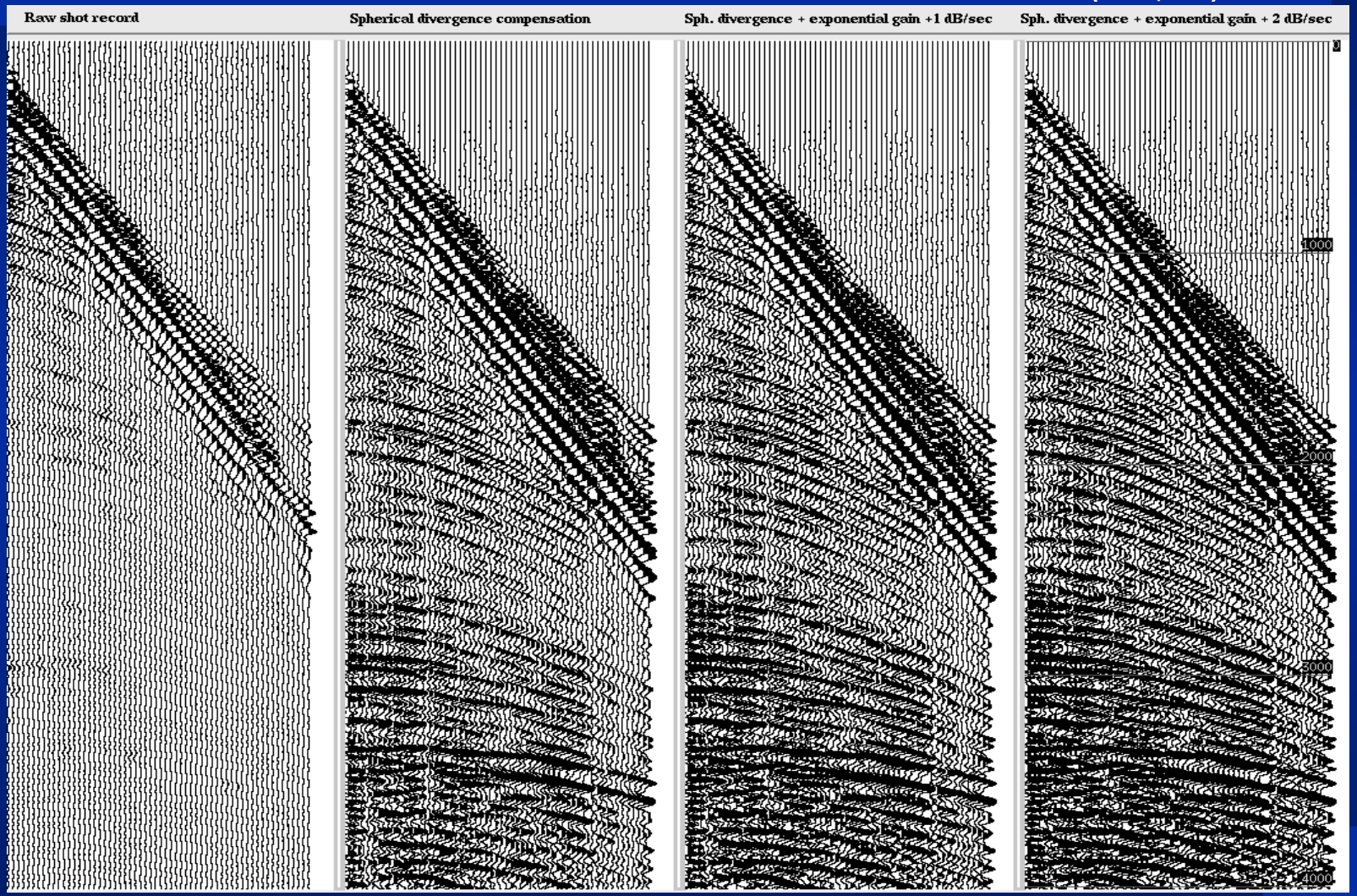
Initial Amplitude Recovery Test

RAW SHOT RECORD	SPHERICAL DIVERGENCE COMPENSATION	SPHERICAL DIVERGENCE + EXPONENTIAL GAIN (1 dB / sec)	SPHERICAL DIVERGENCE + EXPONENTIAL GAIN (2 dB / sec)



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At the end of this Session, you will be able to:

- Understand how applying a gain can affect AVO
- Understand the difference between data dependant & data independent scaling.
- Understand how the different scaling processes are calculated.
- Learn which SFMs apply the scalars discussed in this presentation

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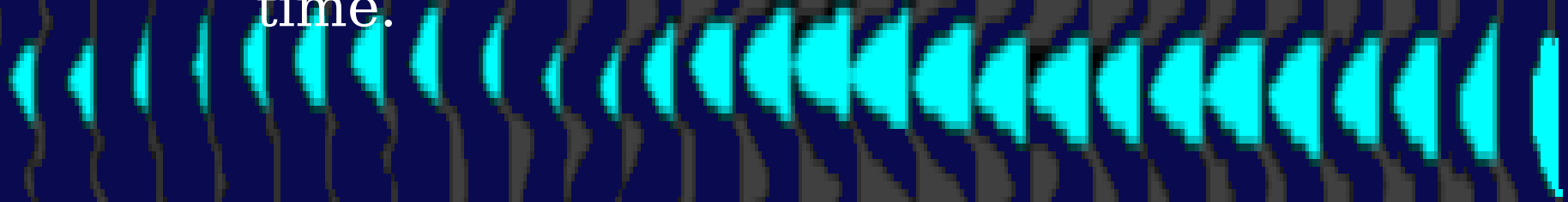
Relative Amplitude Preservation for AVO

Certain rock properties such as porosity & permeability can estimated from studying how amplitude varies with offset at a given time.



This is a prestack CMP gather & you can see the variation.

We must be careful not to destroy these prestack amplitude differences

Data Independent Scaling

ne scaling of any sample will be **independent** of its amplitude.

- Examples are :

  spherical divergence compensation

  exponential gain correction

These amplitude decay corrections will not affect the signal to noise ratio or AVO preservation.

Such scalars can be easily backed off if necessary.

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Data Dependent Scaling

- The scaling of any sample will be **dependent** on its amplitude. I.e. multiply the amplitudes by a value so that the average amplitude = a specified value.

- These scalars would affect AVO calculations.

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Data Dependent Scaling
Which amplitudes to include in our analysis ?

ulti-Window Scaling : the amplitude adjustment is
plied on the basis of several time windows *within the trace.*
nplitude variations occur in both time and space.

Single-Window Scaling: the amplitude adjustment
is
applied by using a single time window. A single scalar
is applied to
all input amplitudes of a trace. It removes variation
from trace
To trace but does not affect amplitude variation
within one trace.

Such scalars DO affect the signal to noise ratio.

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Data Dependent Scaling - Generic method

Multi or Single Window Scaling

1. Define time windows (also known as time gates).
2. Calculate an average amplitude for each window.
3. Compare the average with a standard value - typically $2000_{\mathbf{rms}}$
4. Calculate the scalar and apply to data samples by :

1) Interpolating the scalar values between each calculated value at the centre (usually) of the window and applying them to the data samples.
e.g. SFM **RMS_GAIN** in **Omega**

2) Or sliding the window a sample at a time and applying a separate scalar to each data sample. (Automatic Gain Control)

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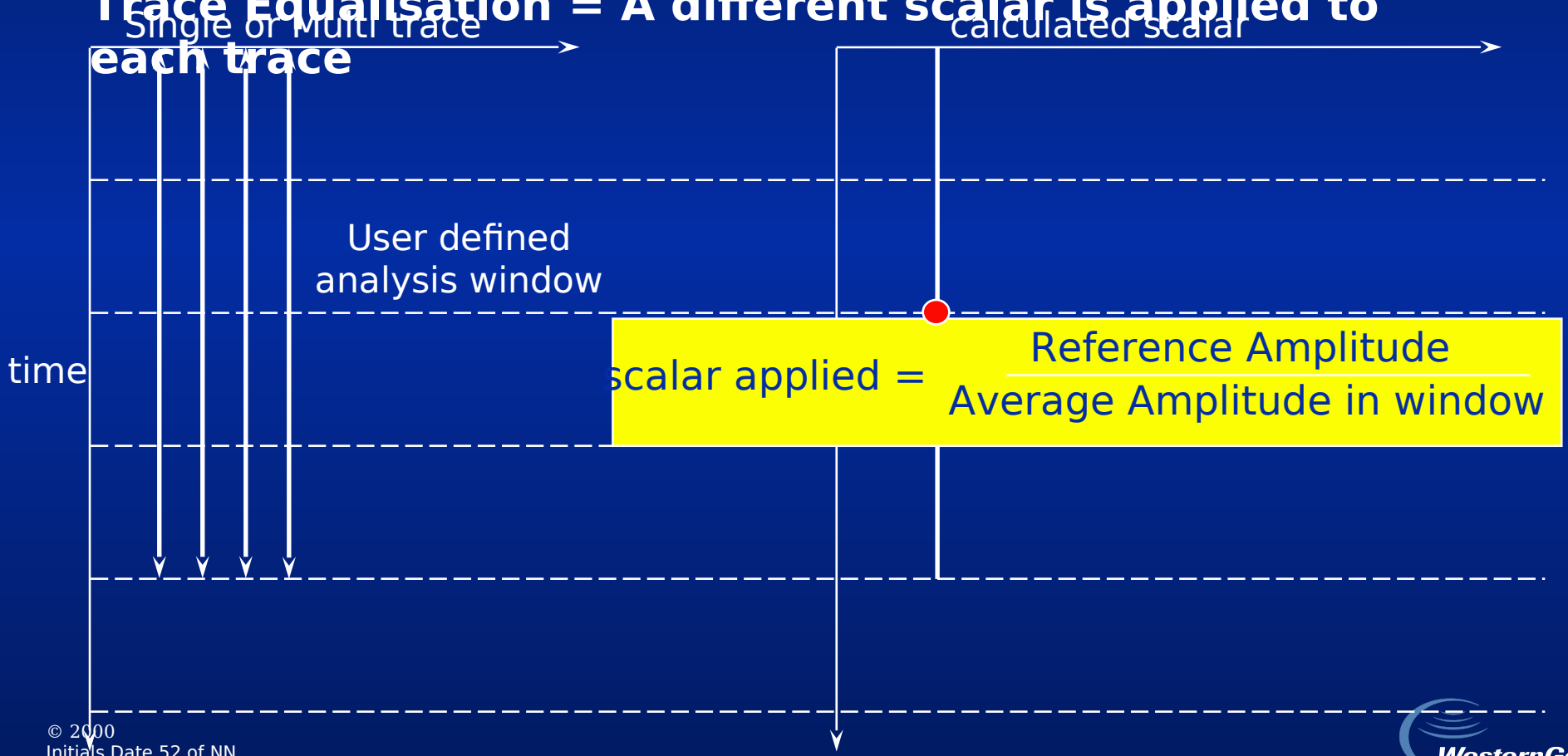
Data Dependant Scaling; Single Window Method

Trace Normalization =The same scalar is applied to all traces

Trace Equalisation = A different scalar is applied to each trace



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Trace Normalization

- A single scalar applied to all traces.
- Single window
- Scalar is derived by using
  - Maximum absolute amplitude measured (A_{max})
  - Average or RMS amplitude
- The Scalar is applied to bring the trace amplitude to a user-specified reference value (ampout)

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Usual Method: $s_{norm} = ampout / A_{max}$

Trace Equalization

Specialized version of Normalization

- Each trace scaled independently - single trace
- Single-window (usually)
- Scalar derived and applied to bring average amplitude to a user-specified value
- Useful for compensating for weak traces (*e.g. within a shot due to poor geophone coupling)*

Caution: Loss of relative amplitude between traces

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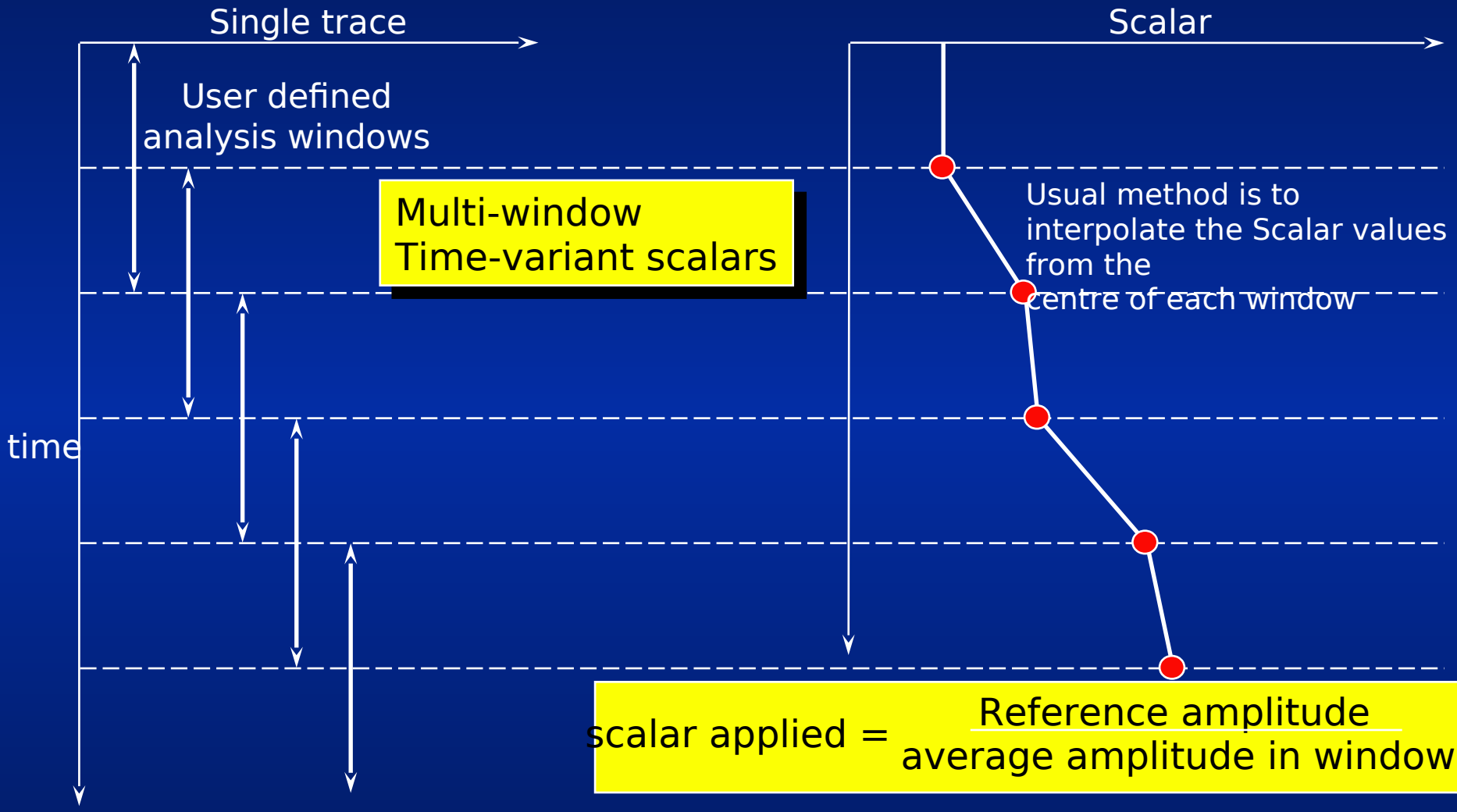
Data Dependent Scaling; Multi-Window Method



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- Space-variant scalars -

  scalars applied vary with offset, shot number, cmp number, receiver station number etc.

- ‘Clipping’ -

  events/samples having amplitude above certain threshold (e.g. percentage of average trace amplitude) truncated prior to calculation of scalar to avoid ‘shadow’ effects.

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More Data Dependent Scaling

ffset amplitude weighting

- Each trace scaled independently
- Magnitude of scalars dependent on offset
- Scalars usually constant in time for each trace/offset
- Most common use - over-emphasis of far offsets where velocity discrimination between primary and multiple energy is greatest

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Omega Amplitude Modules

Some of the **Omega** amplitude modules you will encounter during the course are:

Module	Purpose
GEOSPREAD_COMP	Geometric Spreading Compensation
EXPGAIN	Exponential Gain Application
TRACE_BALANCE	One scalar calculated per trace - Trace Equalisation
RELATIVE_TRC_BALANCE	One scalar calculated per gather – Trace Normalisation
RMS_GAIN	Based on desired RMS Amplitude, interpolation Between analysis windows.
INSTANT_GAIN	Instantaneous AGC Gain. Scalar calculated for Every sample.
PROGRAMMED_GAIN	Input Amplitudes are multiplied by a gain function specified by scalar/time pairs
Time_Function_Gain	Gain function equal to *time in seconds* raised by a specified power…

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Remember

- **The general principle of data processing.**
  - *Manipulate the data as little as possible.*
    - *Only do what is necessary.*

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